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DEVELOPMENT OF COOPERATIVE SHELTER-BELT DEMONSTRATIONS ON THE NORTHERN GREAT PLAINS.

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INTRODUCTION.

To show the possibility of planting trees for shelter belts and to demonstrate the proper methods of starting and caring for these plantings the Northern Great Plains Field Station near Mandan, N. Dak., in the development of one line of its work, has undertaken a cooperation with a number of farmers in the northern Great Plains area. The main objects of the cooperation are to stimulate interest in the improvement of farm homes by planting belts of trees around the farm buildings and to determine by actual trial the species of trees best adapted to the different sections of the region.

THE PLAN OF COOPERATION.

The United States Department of Agriculture undertakes under certain outlined conditions to furnish without charge to farmers living in the territory the trees necessary to plant a suitable shelter belt for the farm buildings. The farmer on his part agrees to plant and care for the trees in accordance with plans and instructions furnished by the department.

The working details of these cooperative shelter-belt demonstrations are issued in a series of five circulars which outline the methods

to be followed in preparing the land for tree planting, in planting the trees, and in cultivating and caring for the trees after planting. Special instructions are given for the planting and care of evergreen or coniferous trees.

Experience has shown that proper preparation of the land is essential to the successful growing of trees in these semiarid plains. The soil must be free from sod and growing grass and must contain at the time of planting a reasonable supply of moisture. Clean summer fallow has been found the most effective tillage method for this purpose. In addition to proper preparation of the land it is necessary to practice clean cultivation until such time as the trees are large enough to practically shade the entire space between the rows. Farmers are required to maintain these conditions as their part of the cooperation.

As the trees are grown under unusually severe conditions, nothing but small stock is used. The age and size of the different species are as follows: Box elder, Russian olive, and Tartarian maple, 1-year seedlings ranging from 6 to 24 inches high; green ash, caragana, and white elm, 2-year seedlings from 12 to 24 inches tall; and poplars, rooted cuttings. The caragana and poplars are cut back to about 8 inches to insure their proper growth after planting.

The conifers are of a necessity older stock, being seedlings transplanted to the field the second year and allowed to grow one or two years, according to the species—jack, Scotch, and western yellow pine are 2–1 transplants; that is, two years in the seed beds and one year in the transplant field. Spruce may be either 2–1, 2–2, or 2–3, according to the size of the original seedlings and the rate of growth made in the transplant fields.

The use of small stock insures a more satisfactory stand than when larger stock is used, besides insuring its delivery to the cooperating farmer in the best condition.

The farmers of this region having come into the northern Great Plains from other more favorable sections, are not familiar with the conditions under which trees may be grown. In addition to the printed instructions in regard to the work, all farmers are visited each summer to check up their work and to see if the plans and instructions have been followed. This has been found to be one of the most essential parts of the work, as without the personal visits and the assistance given by the field men, the farmer soon grows discouraged and often abandons the trees to grow as they may, which results in their failure, due to the growing about them of grass and weeds. The farmer is also furnished cards on which to report the cultivations during the summer and the losses during the first two summers.

AREA COVERED BY SHELTER-BELT DEMONSTRATIONS.

The area covered by this work comprises the western half of the States of North Dakota, South Dakota, and that part of Montana and Wyoming lying east of the Rocky Mountains. The region is roughly 500 miles square and contains a wide variation in topography, soil, and climate. The area is shown inclosed by a heavy line in Figure 1.

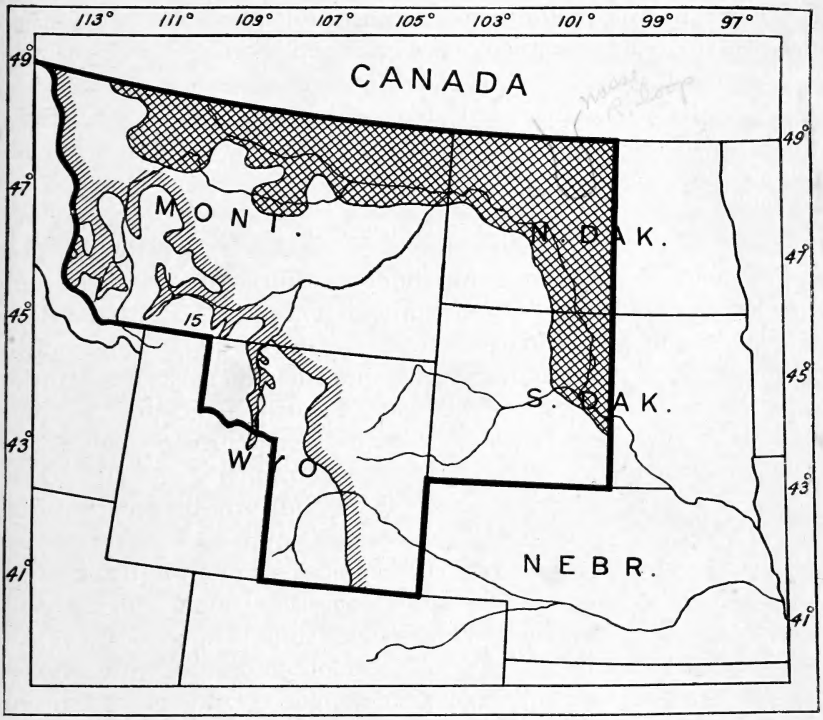

FIG. 1.—Map of the northern Great Plains, showing within the heavy line the area to which the cooperative shelter-belt demonstrations are restricted. The glaciated section of the area is indicated by the crosshatched portion along its northern and eastern sides.

TOPOGRAPHY.[1]

GLACIATED SECTION.

The glaciers at different times extended across the Missouri River for distances ranging from a few miles to 40 or 50 miles. This

[1] Descriptions of the surface features of this region are taken in part from the following publications:

Calhoun, Fred. H. H. The Montana lobe of the Keewatin ice sheet. U. S. Geol. Surv. Prof. Paper 50 (ser. B. Desc. Geol. 79), 62 p., 30 fig., 7 pl. (partly col.), 1906.

Lapham, Macy H., et al. Soil survey of western North Dakota. U. S. Dept. Agr., Bur. Soils, Field Operations—Advance Sheets, 1908, 80 p., 1 fig., 6 pl., 1 col. map, 1910.

Leonard, Arthur Gray. The surface features of North Dakota and their origin. In Quart. Jour., Univ. N. Dak., v. 9, no. 3, April, 1919.

Wright, G. Frederick. The Ice Age in North America and Its Bearing upon the Antiquity of Man, xviii, 648 p., 148 fig., 1 pl., 3 maps. New York and London, 1891.

glaciated area is for the most part an undulating prairie, except for a belt of rough morainic hills called the "Coteau du Missouri." This belt of hills, which marks the limit of the Wisconsin ice sheet, extends diagonally across the State of North Dakota, conforming in general to the course of the Missouri River, but at a distance of some 50 miles more or less to the north and east. It varies from 10 to 20 miles in width and rises in massive hills and ridges strewn with granite bowlders to heights of 150 to 200 feet above the surrounding prairie. Numerous hollows and undrained depressions between these hills and ridges are occupied by swamps and alkaline and fresh-water lakes.

Practically all the glaciated area in Montana is rolling prairie or level stretches of bench land, all of which is well drained. The glaciated area is indicated in Figure 1.

NONGLACIATED SECTION.

The remainder of the region lying between the Missouri River and the foothills of the Rocky Mountains is untouched by the action of the glaciers, and the surface features are almost wholly the result of erosion. It is an area of rolling and for the most part treeless prairies or broad sweeping valleys. The entire section is drained by the Yellowstone and Missouri River systems. So complete a system of watercourses is formed by the tributaries of these rivers that practically the entire surface takes the form of slopes leading into some drainage basin.

Several isolated groups of small mountains rise abruptly from the prairie at a considerable distance from the frontal range of the Rocky Mountains. They are the Black Hills in South Dakota; the Highwood Mountains, the Bearpaw Mountains, the Sweet Grass Hills, and the Larb Hills in Montana. These groups are described by the United States Geological Survey as, for the most part, igneous intrusions and not connected directly with the Rocky Mountains. With the exception of the Larb Hills, they are all covered with a more or less heavy stand of coniferous trees. The heavy growth of western yellow pine that once covered the Bearpaw Mountains now shows the marked effect of thinning through the combined work of settlers and fire.

Another feature of this nonglaciated section is the large number of conical or flat-topped buttes rising several hundred feet above the general level and forming prominent landmarks that can be seen for great distances. These buttes were formed by the erosion of the surrounding soil and are remnants of the ancient Missouri Plateau that once covered the entire section. Notable examples of this formation are the Killdeer and Turtle Mountains in North Dakota, the

Cave Hills and Slim Buttes in South Dakota, and the Pine Hills in southeastern Montana.

SOILS.

There is great diversity in the types of soil that characterize the northern Great Plains region. These soils range from sand and sandy loam through silt and clay loam to heavy clay and shale. In general there is a large proportion of clay in the subsoil, giving it a high water-holding capacity. In certain sections small areas of hardpan are found which the roots of the trees seem unable to penetrate. Cultivation of this type of clay soil is ineffective in making these areas suitable for tree growth. Another small proportion presents a deep gravel subsoil on which trees do not thrive. There are also occasional spots where the percentage of alkaline salts is high enough to stunt or kill out a planting of trees.

A fairly extensive sand-dune area is found in the northeastern corner of the region, in and southeast of the valley of the Mouse River in North Dakota. Here the water table is quite near the surface, and such trees as willow and aspen are found growing naturally in slight depressions that occur in the prairie. Groves of trees planted on timber claims in this area have maintained themselves and made excellent growth.

CLIMATE.

The northern Great Plains are in what is known as the dry-land farming area of the United States. The climate has been classified as semiarid. It may be more accurately described as variable, changing from season to season from almost humid conditions to almost arid, but with a relatively low average annual precipitation ranging from 10 to 20 inches. Another uncertain factor is the seasonal distribution of the rainfall. It is possible for a comparatively low rainfall favorably distributed to produce normal plant growth, while a much higher rainfall unfavorably distributed may result in damage to a plantation through lack of moisture at some critical period of the growing season. Very high summer temperature and very low winter temperature, coupled with frequent strong winds throughout the entire year, combine to make this one of the most severe regions for tree growth in the United States.

Table 1 gives the highest, lowest, and average seasonal and annual precipitation at 10 field stations of the Bureau of Plant Industry in the area for the 5-year period from 1916 to 1920, inclusive. It also gives the average seasonal evaporation for the same years. Most of these stations have United States Weather Bureau records of precipitation covering a period of 15 to 45 years. The average precipitation for the entire period of the record is given in the table.

TABLE 1.—*Precipitation and seasonal evaporation at 10 field stations in the northern Great Plains for the 5-year period from 1916 to 1920, inclusive.*

Station.	Altitude (feet).	Precipitation (inches).							Evaporation, seasonal[1] (inches).
		Seasonal.[1]			Annual.			Normal annual.[2]	
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.		
Mandan, N. Dak.	1,750	11.38	9.22	10.15	15.07	10.31	12.96	17.05	35.460
Dickinson, N. Dak.	2,543	13.89	5.82	10.18	18.21	8.35	12.81	15.77	34.158
Hettinger, N. Dak.	2,253	13.18	6.39	10.11	15.91	7.85	12.74	14.96	32.762
Newell, S. Dak.	2,950	20.56	8.44	12.78	25.89	13.32	17.03	15.20	34.174
Ardmore, S. Dak.	3,557	17.53	10.57	13.29	20.26	13.53	16.66	17.55	37.274
Havre, Mont.	2,505	14.88	4.85	8.57	19.24	7.56	11.68	13.67	35.727
Moccasin, Mont.	4,200	15.63	4.77	10.74	19.87	9.90	16.44	16.61	35.335
Huntley, Mont.	3,037	9.87	5.31	7.88	15.14	12.22	13.62	13.84	34.256
Sheridan, Wyo.[3]	3,790	12.41	5.28	8.60	17.38	8.56	13.52	14.72	35.525
Archer Wyo.	6,017	15.59	8.53	11.62	19.09	12.39	14.79	13.60	36.845

[1] Seasonal precipitation and evaporation are for the 6-month period from Apr. 1 to Sept. 30, inclusive.
[2] Mean annual precipitation is the average of the entire record.
[3] Sheridan data, except mean annual precipitation, are for the four years from 1917 to 1920, inclusive.

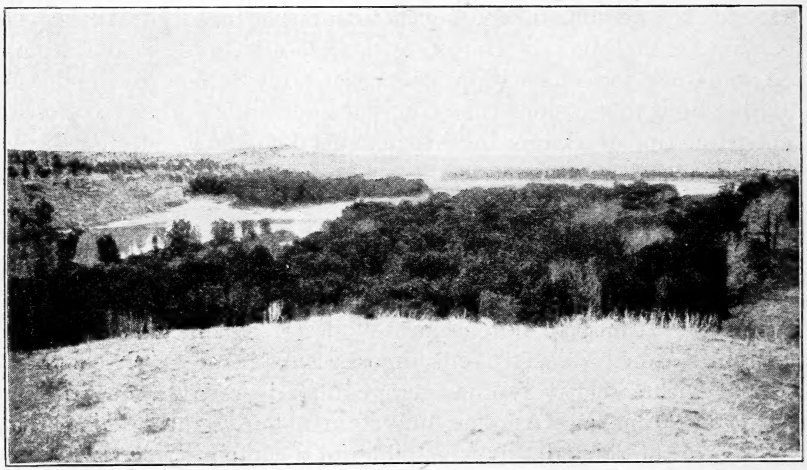

FIG. 2.—The Yellowstone River valley at Pompeys Pillar in southern Montana, showing native growth of western cottonwood, box elder, and green ash in the river bottom and yellow pine on the adjoining hills.

NOTES ON TREE SPECIES.

In determining the adaptability of any tree species for planting on the open prairie of this region, its ability to resist drought and extreme cold is a factor of prime importance. In this area of limited moisture, late spring frosts, and early autumn frosts it is found that many of the species adapted to shelter-belt use have a comparatively short growing season. Their leaves are not put out until spring is well advanced and terminal buds are generally set in late summer. It naturally follows that the native tree growth found along the rivers and in the coulees and on certain groups of hills throughout

the region furnishes what is perhaps the most important source of material for shelter-belt planting.

Figure 2 shows the native growth of western cottonwood, box elder, and green ash in the river bottom, with western yellow pine on the adjoining hills in the Yellowstone River valley at Pompeys Pillar in southern Montana.

Figure 3 is a view in the Turtle Mountains, Bottineau County, N. Dak., showing the native tree growth, consisting of cottonwood, balsam poplar, aspen, white elm, bur oak, and green ash.

The species that make up this native growth are of two general classes: Those which have progressed up the Mississippi-Missouri River system from the east and those which have advanced down the western sources of this same system from the Rocky Mountains.

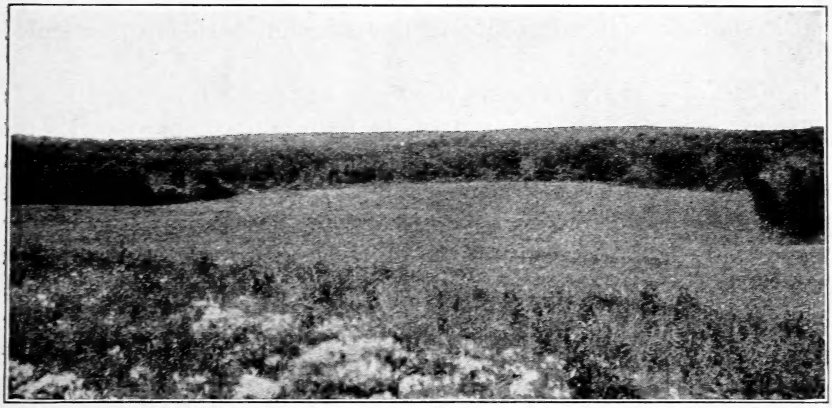

FIG. 3.—View in the Turtle Mountains, Bottineau County, N. Dak., showing native tree growth consisting of cottonwood, balsam, poplar, aspen, white elm, bur oak, and green ash.

Beside these native trees a number of species have been introduced from other parts of the United States and Canada and from certain European and Asiatic countries. Some of these introduced species are fully as adaptable to shelter-belt use as any of the native species, while a number of the native trees can not be successfully transplanted to the open plains.

The following paragraphs give brief descriptions of practically all of the trees which have been used in shelter-belt planting in the northern Great Plains region. The list is not exhaustive, however, as there are a number of other species that can doubtless be made to grow, but about which little data are available at the present time.

DECIDUOUS OR HARDWOOD SPECIES NATIVE TO THE REGION.

Box elder.—The box elder (*Acer negundo*) is found in practically all of the river valleys to the foothills of the Rocky Mountains.

It is rarely found growing very far from the moist bottom lands and does not push its way up the dry coulees toward the prairie levels. It is, however, a very useful tree for prairie planting, adapting itself readily to upland conditions, and has been known to persist in sod for a number of years after attaining reasonable size under cultivation. It may be classed as one of the best for shelter-belt planting in all types of soil throughout the entire region.

Green ash.—The green ash (*Fraxinus lanceolata*) is found in much the same range as the box elder. It prefers somewhat drier sites and often works its way up the long open coulees to the level of the prairie. In these situations it is frequently mixed with white elm, June berry, wild plum, buffalo berry, and chokecherry. It ranks with the box elder as one of the best trees for shelter-belt planting, doing well on all types of soil except sand and gravel, and it shows a marked ability to live through periods of extended drought.

White elm.—The white elm (*Ulmus americana*) though generally considered a moisture-loving tree, is found in company with the green ash and buffalo berry in such comparatively dry situations as open valleys far removed from running water. Here it maintains itself in sod on the sides of dry runs. This occurs more generally at the western limit of its range, which is in eastern Montana and the Black Hills of South Dakota. In the Plains region it departs somewhat from its usual graceful shape, old trees at a distance resembling gnarled oaks. It is a good tree in shelter-belt plantings, showing a preference for clay soils. It is difficult to get seed for propagation, as the blossoms are often injured by the late spring frosts.

Western cottonwood.—The western cottonwood (*Populus deltoides* var. *occidentalis*) is the dominant tree species along the larger river valleys of the Great Plains where it often attains great age, forming extensive open groves. It grows at some distance from its usual bottom-land habitat and may occasionally be found far up some dry run. It is a very good tree in shelter-belt planting throughout the area east of the Missouri River; farther west, however, it does not succeed as well. It adapts itself to either sand or clay soils, but is not to be recommended for dry situations.

Balsam poplar.—The balsam poplar (*Populus balsamifera*) is found in the Black Hills in South Dakota; the Turtle Mountains, the Mouse River Valley, and on lake shores in the Coteau du Missouri in North Dakota; and possibly in the Little Rocky Mountains and the Sweet Grass Hills in Montana. The tree has not been planted for shelter-belt purposes except in a limited area south of the Turtle Mountains in North Dakota. As it is essentially a

northern tree, ranging nearly to the Arctic Circle, it may not adapt itself to the hot summer temperatures of the Great Plains.

Aspen.—The aspen (*Populus tremuloides*) is scattered sparsely over portions of the Plains region. It is found in the river valleys, on the north sides of small mountain groups, on occasional steep bluffs, and in the sand-dune area near the Mouse River in North Dakota. It is also found on the borders of lakes in the Coteau du Missouri and in depressions or coulees in the prairie where underground springs exist. It has been used in some instances for farm plantings, and makes a dense growth, though of no great size.

Northwest poplar.—The northwest poplar (*Populus* sp.) was given its name by one of the commercial nurseries in North Dakota. It was discovered in the northern part of that State, and is supposed

FIG. 4.—Northwest poplar (row at left) in its fourth year of growth in a shelter belt in Sheridan County, N. Dak.

to be a natural hybrid presumably between the balsam poplar and the aspen. Whatever its origin, it is the most promising poplar for shelter-belt planting in the Great Plains area that has yet been tested. It is perfectly hardy, seems to grow on all types of soil, and is superior to the cottonwood on the drier locations. Figure 4 shows the northwest poplar in its fourth year of growth in a shelter belt in Sheridan County, N. Dak.

Acute-leaved cottonwood.—The acute-leaved cottonwood (*Populus acuminata*) is native to the foothills of the Rocky Mountains. It is found along the banks of streams in Montana as far east as the Powder River and in Wyoming to the Black Hills in South Dakota. This tree has been used for street planting in cities of the Rocky Mountain region, and is superior for that purpose to the common

cottonwood (*P. deltoides*). It has not yet been tested throughout the Great Plains region as a shelter-belt tree.

Narrow-leaved cottonwood.—The narrow-leaved cottonwood (*Populus angustifolia*) prefers moister situations than its related species, and clings closely to the river and creek margins and low flood lands. It is a Rocky Mountain species, having a range much more restricted than the acute-leaved poplar. It has been planted as a street tree within its range, but it makes a poor showing for this purpose. Its usefulness for shelter-belt planting is doubtful.

Diamond willow.—The diamond willow (*Salix mackenzieana*) is found generally throughout the Great Plains area. It follows the river and creek bottoms to the foothills of the Rocky Mountains. It is a tree of some economic importance as a source of fence posts. It has been planted in shelter belts on the prairie with only fair success.

Bur oak.—The bur oak (*Quercus macrocarpa*) is found as far west as the Black Hills and in the Bad Lands of western North Dakota, southeastern Montana, and northeastern Wyoming. It grows on the drier sites along stream banks and old flood plains, occasionally venturing to the lower prairie levels. It does not grow to a great size, though specimens are found of apparent great age. It has not been considered a practical tree for transplanting to shelter-belt sites.

Chokecherry.—The chokecherry (*Prunus virginiana*) ranges throughout the entire Great Plains region along the river courses and up the dry coulees to the prairie levels, where it is often found associated with the green ash. It is well adapted for shelter-belt planting, doing well in all situations except very sandy or low wet soils.

Buffalo berry.—The buffalo berry, or bullberry (*Shepherdia argentea*), is closely associated with the chokecherry in range and adaptability for shelter-belt planting. It is more suited to the sandy types of soil, but does not favor low wet situations.

CONIFEROUS OR EVERGREEN SPECIES NATIVE TO THE REGION.

Black Hills spruce.—The Black Hills spruce (*Picea canadensis*), a form of white spruce found in the Black Hills of South Dakota, has certain characteristics which distinguish it from the common white spruce of northern Minnesota and Canada. It is not exacting as to soil types, but prefers the drier locations. It is one of the best evergreens for shelter-belt planting in the northern Great Plains.

Figure 5 shows spruce on the east side of the deciduous shelter belt at the Northern Great Plains Field Station, Mandan, N. Dak. The three rows from left to right are blue spruce, white spruce, and Black Hills spruce. The relatively greater size of the Black Hills spruce

is partly due to its being the outside row, farthest from the deciduous trees.

Western yellow pine.—The western yellow pine, or bull pine (*Pinus ponderosa*), is found extensively over the western portion of the northern Great Plains area on the hills and rocky outcrops from the Little Missouri River and the Black Hills to the Rocky Mountains. It is an extremely hardy tree in its natural habitat, but as yet has not been transplanted to prairie situations with much success. It is probably suited to special localities, but present data do not recommend it for general use.

Lodgepole pine.—The lodgepole pine (*Pinus murrayana*) is found at low altitudes in the Rocky Mountains and in the outlying groups

FIG. 5.—Spruce in a planting at the Northern Great Plains Field Station, Mandan, N. Dak. The row on the left center is blue spruce, the center row is white spruce, and the one at the right is Black Hills spruce.

of small mountains in the Great Plains region where it is confined principally to the northern slopes. It has proved adaptable for shelter-belt planting in Alberta and Saskatchewan, Canada, but has not yet been tested in the United States.

Douglas fir.—The Douglas fir (*Pseudotsuga taxifolia*) extends east from the Rocky Mountains in company with western yellow pine to central Montana. It is found in the coulees, or "breaks," along the Missouri River up to the very edge of the prairie. It may be classed with the western yellow pine in adaptability for shelter-belt planting.

Red cedar.—The red cedar, or juniper (*Juniperus virginiana*), grows as a low, shrubby tree among the rough hills overlooking the river valleys of the region. It is extremely hardy and makes good growth when transplanted. It has not been used, however, for shelter-belt planting to any extent.

DECIDUOUS OR HARDWOOD SPECIES INTRODUCED TO THE REGION.

Carolina poplar.—The Carolina poplar (*Populus* sp.) is propagated by commercial nurseries and has been widely used in past years for shelter-belt planting on the prairies east of the northern Great Plains region. It is probably a selection of the common cottonwood taken in the central or eastern United States. Extensive tests with this variety in shelter belts on the northern Great Plains have proved it entirely unsuited for general planting in this region.

Norway poplar.—The Norway poplar (*Populus* sp.) is propagated extensively by commercial nurseries. It closely resembles the Carolina poplar. Extensive tests in shelter-belt plantings in the northern Great Plains indicate that it is unsuited for general planting in this section.

Canadian poplar.—The Canadian poplar (*Populus* sp.) is one of several varieties imported a number of years ago from northern

FIG. 6.—Shelter-belt planting of box elder, northwest poplar, and green ash planted 6 by 6 feet at Archer, Mont., showing clean cultivation in the first year of growth.

Russia or Siberia and propagated by commercial nurseries in the United States and Canada. This variety has been extensively planted in the Plains region of Canada, where it has proved quite adaptable for shelter-belt use. Plantings in the Plains region of the United States, however, have shown that it is subject to attack by canker, which kills the trees in three or four years. This disease makes it a questionable variety for general use in this region.

Laurel-leaf willow.—The laurel-leaf willow (*Salix pentandra*) is extensively propagated by commercial nurseries for shelter-belt planting in the Northwest. It was imported a number of years ago from Europe. While it is reasonably hardy, it does not seem able to establish itself in the upland prairie locations on the Great Plains. Extensive test plantings have grown nicely for one or two years and then killed out for what seems to be lack of sufficient moisture.

It can not be recommended for general planting in this section. It seems, however, to be well adapted for planting on the prairies in the eastern part of the Dakotas and in western Minnesota.

Russian golden willow.—The Russian golden willow (*Salix vitellina*), like the laurel-leaf willow, has been extensively propagated by commercial nurseries for planting in the Northwest. It was imported a number of years ago from Russia. It has been extensively tested throughout the Great Plains area and has killed out over large areas after one or two years, the same as the laurel-leaf willow. It can not be recommended for general planting in this section, but it seems to do well on the prairies farther east.

Honey locust.—The honey locust (*Gleditsia triacanthos*) is native to southern Minnesota and South Dakota. It is hardy in a few isolated sections of the northern Great Plains, but can not be recommended for general planting.

FIG. 7.—A 5-year old planting of box elder, green ash, and white elm in Ziebach County, S. Dak. This illustration shows the trees filling the spaces between the rows which are 8 feet apart.

Caragana.—The caragana, or Siberian pea tree (*Caragana arborescens*), is an importation of some years back from Siberia. It is especially hardy and drought resistant and is one of the best trees for general shelter-belt planting in the northern Great Plains. It is adapted to all types of soil except sand or gravel, but does not thrive in low, wet situations.

Russian olive.—The Russian olive (*Elaeagnus angustifolia*) is an importation made some years ago from northern Russia. Like the caragana, it is especially hardy and drought resistant and may be classed with it as a valuable tree for shelter-belt planting in the northern Great Plains area. It adapts itself to all types of soil, but does not thrive in low, wet situations.

Chinese elm.—The Chinese elm (*Ulmus pumila*) was introduced several years ago from northern China. It has not proved entirely hardy in the northern portion of this region, where a tendency is

shown to winterkilling and drying out for lack of moisture. In certain sections it has made an excellent growth, but it can not yet be recommended for general use.

CONIFEROUS OR EVERGREEN SPECIES INTRODUCED TO THE REGION.

Scotch pine.—The Scotch pine (*Pinus sylvestris*) is a native of northern Europe and Asia and has been widely planted in the United States. It grows successfully on the prairies east of the Great Plains region, and recent plantings within the region indicate that it is one of the best evergreens for shelter-belt use. It is not as well adapted to sand and gravel soil as the jack pine and does not do well in moist or low, wet situations.

Jack pine.—The jack pine (*Pinus divaricata*) is found extensively on the more sandy soils of northern Minnesota. It is adapted to shelter-belt planting on the Great Plains, especially on sandy soil.

FIG. 8.—A shelter belt near Isabel, S. Dak. In the foreground are Scotch pines planted in 1920 and jack pines planted in 1921 in east and west rows on the south side of the broadleaf section planted in 1916. Photographed in July, 1921.

It does not do well on clay soil and should not be placed in moist or low, wet situations.

White spruce.—The white spruce (*Picea canadensis*) has a wide range in northern Minnesota and Canada. It is adapted to shelter-belt planting on the Great Plains and is suitable for practically all types of soil. It will grow in either wet or dry situations.

Blue spruce.—The blue spruce, or Colorado blue spruce (*Picea parryana*), is native to the Rocky Mountains of Colorado, Utah, and Wyoming. It appears to be perfectly hardy when planted in shelter belts in the northern Great Plains. It is more exacting as to soil requirements than the white spruce, showing preference for clay soils.

TREES IN RELATION TO SOIL TYPES.

Not all species of trees adapted to this region grow equally well on the same type of soil. The typical shelter-belt planting site is on the open upland prairie where the soil texture falls into the general

classifications of clay or silt loam, sandy loam, and sand or gravel and the moisture supply is derived entirely from the rainfall. Exceptional planting sites are found where lack of drainage or nearness to streams and water tables affords a moist or low, wet soil condition. Table 2 lists the several tree species according to their adaptability to the above rough classification.

TABLE 2.—*Adaptation of tree species to the several soil types or conditions on the Northern Great Plains.*

Clay or silt loam.	Sandy loam.	Sand or gravel.	Moist soils.	Low wet soils.
Box elder	Box elder	Box elder	Box elder	Box elder.
Northwest poplar	Northwest poplar	Northwest poplar	Northwest poplar	Northwest poplar.
Green ash	Green ash		Green ash	Green ash.
White elm			White elm	White elm.
Caragana	Caragana		Caragana	
Buffalo berry	Buffalo berry	Buffalo berry	Buffalo berry	
Russian olive	Russian olive	Russian olive	Russian olive	
Chokecherry	Chokecherry		Chokecherry	
			Cottonwood	Cottonwood.
White spruce	White spruce	White spruce	White spruce	White spruce.
Black Hills spruce	Black Hills spruce	Black Hills spruce	Black Hills spruce	
Blue spruce	Blue spruce		Blue spruce	
Scotch pine	Scotch pine			
	Jack pine	Jack pine		
			Willow [1]	Willow.[1]

[1] Laurel-leaf Russian golden, or diamond willow.

FIG. 9.—A shelter belt planted in 1916 that is an effective factor in the development of a home on the treeless plains at Fowler, Mont. Photographed in 1921.

SHELTER-BELT PLANTING PLANS.

The demonstration shelter belts are laid out in long belts ranging from 5 to 10 or more rows spaced 8 feet apart. In most of the plantings the trees have been placed 4 feet apart in the row. Recent observations made of the plantings set out in 1916 indicate that a wider spacing might be better, especially for the average site, in order that the individual trees may reach a larger size be-

fore competition with the adjacent trees for the soil moisture begins. There is a generally accepted belief that close spacing is desirable in order that the trees may quickly grow together and shade the ground, thus keeping out the grass and weeds. Careful cultivation must be practiced until this result is attained. Wider spacing of trees naturally lengthens the period during which cultivation is necessary. The guiding principle for spacing, therefore, is to plant the trees as close together as possible without forcing them to compete with each other for moisture at too early an age. It seems probable that 6 by 8, 8 by 8, or 6 by 10 feet apart are preferable to closer distances in this section.

Figure 6 shows clean cultivation in the first year of a planting spaced 6 by 6 feet at Archer, Mont. The light-colored row is northwest poplar.

FIG. 10.—A planting made in 1917 at Dupree, S. Dak. The trees have had clean cultivation and made good growth. Photographed in 1921.

Figure 7 shows a planting of box elder, green ash, and white elm in Ziebach County, S. Dak. The rows in this planting were 8 feet apart. The photograph, taken in the fifth year of growth, shows that the trees have met and fill the spaces between the rows.

The selection of species and their arrangement are made with the view of establishing a dense shade that will exclude the sunlight both from above and on the sides. Outside rows are planted to low-growing species, such as caragana, Russian olive, chokecherry, and buffalo berry. The interior of the belt is planted to alternating rows of box elder and green ash, green ash and white elm, box elder and poplar, or a combination of all these species.

The ideal tree for shelter is the conifer, or evergreen. It is found, however, that in this region it is necessary to provide some kind of shelter for them when they are first planted. A plan has been

adopted of setting out a shelter belt of deciduous species as described above and later adding evergreens along the sheltered edge or inside of the original planting. Care must be taken to leave a space of some 20 feet between the two plantings, or the small evergreens may suffer from competition with the roots of the older planting for moisture.

Figure 8 shows Scotch pine planted in 1920 and jack pine planted in 1921 in east and west rows on the south side of the hardwood shelter belt planted in 1916. This planting is near Isabel, S. Dak. The photograph was taken in July, 1921.

FIG. 11.—Box elder and green ash planted in 1918 in western North Dakota and abandoned to weeds after being cultivated two years. Trees can not compete in this section with annual weeds or perennial grass.

DEMONSTRATION PLANTINGS.

All of the planting stock used in these shelter-belt demonstrations, except the Chinese elm, was grown either from seed or cuttings or as transplants in the nursery at the Northern Great Plains Field Station. Tables 3 to 6, inclusive, give the number and kind of trees sent out for planting in each of the four States in the territory covered by this work, during the 5-year period from 1916 to 1920, inclusive.

The shipments of each kind of stock to cooperators in each State in 1916 are shown in Table 3. Shipments of planting stock totaled 701,911. A little over half of this number consisted of willow and poplar cuttings which were made up of approximately equal numbers of laurel-leaf willow, Russian golden willow, Norway poplar, and Carolina poplar. The summer season of 1916 was one of very favor-

able moisture conditions, and a large percentage of these cuttings took root and made good growth. In northern Montana an early frost occurring in August caused some damage. During the winter of 1916–17 nearly all the trees were injured by freezing to some extent, but none as severely as the willow and poplar.

Details of the 1917 shipments, which totaled 357,700, are also given in Table 3. White elm was used for the first time this year and, although the summer was very dry, made an excellent growth. The Norway and Carolina poplars proved so unsatisfactory in both 1916 and 1917 that their use was discontinued. Cuttings of both willow and poplar were almost a complete failure under the dry conditions that prevailed, and the further use of cuttings for demonstration plantings was discontinued.

TABLE 3.—*Number of trees of each species or kind of stock shipped to cooperators in each State in 1916 and 1917.*

Season and State.	Species or kind of stock.								Total.
	Willow (cuttings).	Willow (rooted).	Poplar (cuttings).	Poplar (rooted).	Box elder.	Green ash.	Caragana.	White elm.	
Season of 1916:									
Montana	126,506	10,283	120,983	15,291	140,550	3,964	33,977	.....	451,554
North Dakota	30,408	4,139	28,279	5,562	37,159	12,969	13,287	.....	131,803
South Dakota	23,708	1,233	26,580	1,157	25,519	100	5,626	.....	83,923
Wyoming	9,504	294	9,243	2,073	10,185	.....	3,332	.....	34,631
Total	190,126	15,949	185,085	24,083	213,413	17,033	56,222	.....	701,911
Season of 1917:									
Montana	6,211	65,002	.....	16,114	39,798	69,600	2,163	27,982	226,870
North Dakota	2,512	20,507	.....	4,244	14,995	30,473	922	10,906	84,559
South Dakota	638	8,703	.....	2,044	6,771	9,338	283	4,154	31,931
Wyoming	.....	4,379	.....	2,748	3,667	2,412	505	629	14,340
Total	9,361	98,591	.....	25,150	65,231	111,823	3,873	43,671	357,700

Figure 9 shows one of the 1916 plantings, made near Fowler, Mont., that is becoming an effective unit in the development of a farm home on the Plains.

Figure 10 is reproduced from a photograph taken in 1921 of one of the 1917 plantings at Dupree, S. Dak. The trees have had clean cultivation and made good growth. After one or two more seasons' growth the trees will meet between the rows and cultivation cease.

Figure 11 shows one of the plantings made in 1918 in western North Dakota that was abandoned to weeds after two years of cultivation. Trees on upland in this section can not compete with perennial grasses and annual weeds.

Shipments in 1918 totaled only 142,302. The number of each species sent to each State is shown in Table 4. The marked reduction in the amount of planting stock sent out was due to the severe drought of 1917, which caused great loss to the trees grown at the station nursery.

The season of 1918 was one of deficient rainfall over practically the entire area. The willows were most affected by the successive dry conditions of 1917 and 1918. Those planted in 1916 and 1917 showed extensive winter injury.

TABLE 4.—*Number of trees of each species or kind of stock shipped to cooperators in each State in 1918 and 1919.*

Season and State.	Species or kind of stock.								Total.
	Willow (rooted).	Box elder.	Green ash.	Caragana.	Chinese elm.	Scotch pine.	Western yellow pine.	Jack pine.	
Season of 1918:									
Montana	22,242	14,843	24,424	20,617	2,390	.....	.....	.....	84,516
North Dakota	7,142	4,993	8,456	9,607	490	.....	.....	.....	30,688
South Dakota	5,952	3,984	7,707	2,397	200	.....	.....	.....	20,240
Wyoming	1,880	1,139	1,947	1,772	120	.....	.....	.....	6,858
Total	37,216	24,959	42,534	34,393	3,200	.....	.....	.....	142,302
Season of 1919:									
Montana	40,041	2,228	27,371	4,355	211	2,075	1,775	1,850	79,906
North Dakota	30,645	9,650	18,490	1,596	15	750	500	500	62,146
South Dakota	7,629	223	5,322	226	26	1,375	550	1,300	16,651
Wyoming	1,948	102	1,004	55	.....	250	250	250	3,859
Total	80,263	12,203	52,187	6,232	252	4,450	3,075	3,900	162,562

A shipment of Chinese elm was received from the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture for trial in this section. These trees were sent to 20 selected farmers and made good growth in all cases.

Details of the distribution of 162,562 trees shipped to cooperators in 1919 are also given in Table 4.

TABLE 5.—*Number of trees of each species or kind of stock shipped to cooperators in each State in 1920.*

State.	Species or kind of stock.									Total.
	Northwest poplar.	Box elder.	Green ash.	Buffalo berry.	Tartarian maple.	Scotch pine.	Western yellow pine.	Jack pine.	Blue spruce.	
Montana	2,506	28,262	17,259	608	1,371	9,405	4,821	1,946	1,285	67,463
North Dakota	.....	13,766	9,223	.....	.....	472	1,645	3,690	468	29,264
South Dakota	600	9,685	4,669	135	40	3,635	549	706	52	20,071
Wyoming	.....	3,863	1,561	.....	.....	399	249	1,313	.....	7,385
Total	3,106	55,576	32,712	743	1,411	13,911	7,264	7,655	1,805	124,183

The drought continued in 1919, making the third successive year of dry conditions. Except in especially favorable locations the willow was rapidly dying out over the entire area and its further use was discontinued. The small number of Chinese elm listed was used in making replacement to the plantings made in 1918, which in most instances came through the winter in fine condition and made excellent growth during the summer. Coniferous trees obtained from

the Forest Service nursery, Halsey, Nebr., and grown for one year at Mandan, N. Dak., were sent out to 23 selected farmers. These plantings were almost total failures on account of the very dry soil condition at the time they were set out.

In 1920, shipments to cooperators totaled 124,183 trees. The distribution of the shipments by species and States is given in Table 5.

The year 1920 was one of drought over nearly the entire territory, making the fourth year in succession in which the rainfall was below normal. Tartarian maple and buffalo berry were used

TABLE 6.—*Summary of Tables 3 to 5, inclusive, showing the total number of trees of all species shipped to cooperators in each State for each year of the 5-year period from 1916 to 1920, inclusive.*

State.	1916	1917	1918	1919	1920	Total.
Montana	451,554	226,870	84,516	79,906	67,463	910,309
North Dakota	131,803	84,559	30,688	62,146	29,264	338,460
South Dakota	83,923	31,931	20,240	16,651	20,071	172,816
Wyoming	34,631	14,340	6,858	3,859	7,385	67,073
Total	701,911	357,700	142,302	162,566	124,183	1,488,658

for the first time in a few places. Coniferous plantings were again almost total failures, on account of dry soil conditions. It is probable that this type of tree can only be established in years of favorable rainfall.

Northwest poplar, which had grown successfully in test plantings at Mandan for four years, was sent out for the first time to a few selected cooperators.

TABLE 7.—*Number of cooperative shelter belts planted each year, the number of each year's plantings listed as successful or as having failed on January 1, 1921, and the percentage of failures.*

Year.	Number planted.	Number successful on Jan. 1, 1921.	Number that had failed by Jan. 1, 1921.	Percentage of failures.
1916	633	319	314	49.6
1917	232	117	115	49.5
1918	75	37	38	50.6
1919	202	154	48	23.7
1920	92	89	3	3.3
Total	1,234	716	518	42.0

In Table 6 the shipments of trees to cooperators during the 5-year period from 1916 to 1920, inclusive, are summarized to show the number shipped to each State each year, the total shipments each year, and the total number sent to each State in the five years. In the five years, 910,309 trees were shipped to Montana, 338,460 to North Dakota, 172,816 to South Dakota, and 67,073 to Wyoming. The total number of trees in shipments to the four States in the five years was 1,488,658.

Table 7 shows the number of shelter belts planted by cooperators with trees furnished by the Northern Great Plains Field Station during the 5-year period from 1916 to 1920, inclusive. It also shows the number of the plantings made each year that were listed as successful on January 1, 1921, the number listed on that date as having failed, and the percentage of failures. In the five years 1,234 plantings were made and at the end of the period 716, or 58 per cent, of these were listed as successful and 518, or 42 per cent, as having failed. Almost exactly 50 per cent of the plantings made in each of the years 1916, 1917, and 1918 were listed as successful at the end of the 1920 growing season.

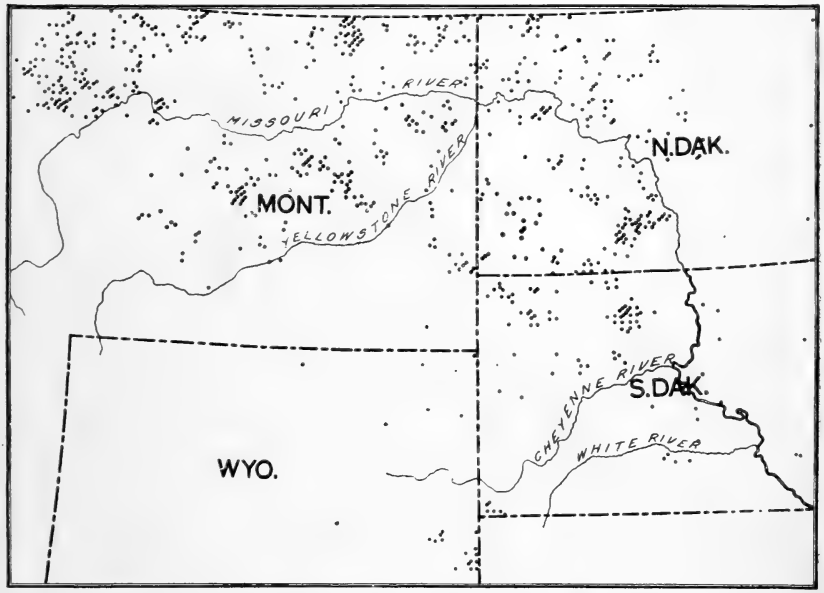

FIG. 12.—Outline map of the Northern Great Plains region. Each township in which one or more plantings of shelter belts had been made in 1917 or in which application had been made for planting in 1918 is indicated by a dot.

Failures may be and were due to any one or more of several causes. The more frequent causes have been improper planting, lack of care and cultivation, prolonged drought, and the owner leaving the farm. The years from 1917 to 1920, inclusive, were all years of severe drought over the greater part of the territory covered by the shelter-belt work. Such a succession of drought years is unprecedented in the time for which records are available. The work has consequently been in progress during the most unfavorable years it is likely to experience. Continued drought leads to economic stress which is reflected on such projects as this either by abandonment of the farm or inability to properly care for and protect the plantings. Considering the unusual stress of climatic and economic conditions, it is

gratifying that the percentage of failures is no higher than it is. It is felt that under the conditions obtaining the percentage of successes is very satisfactory and indicates not only the possibilities of

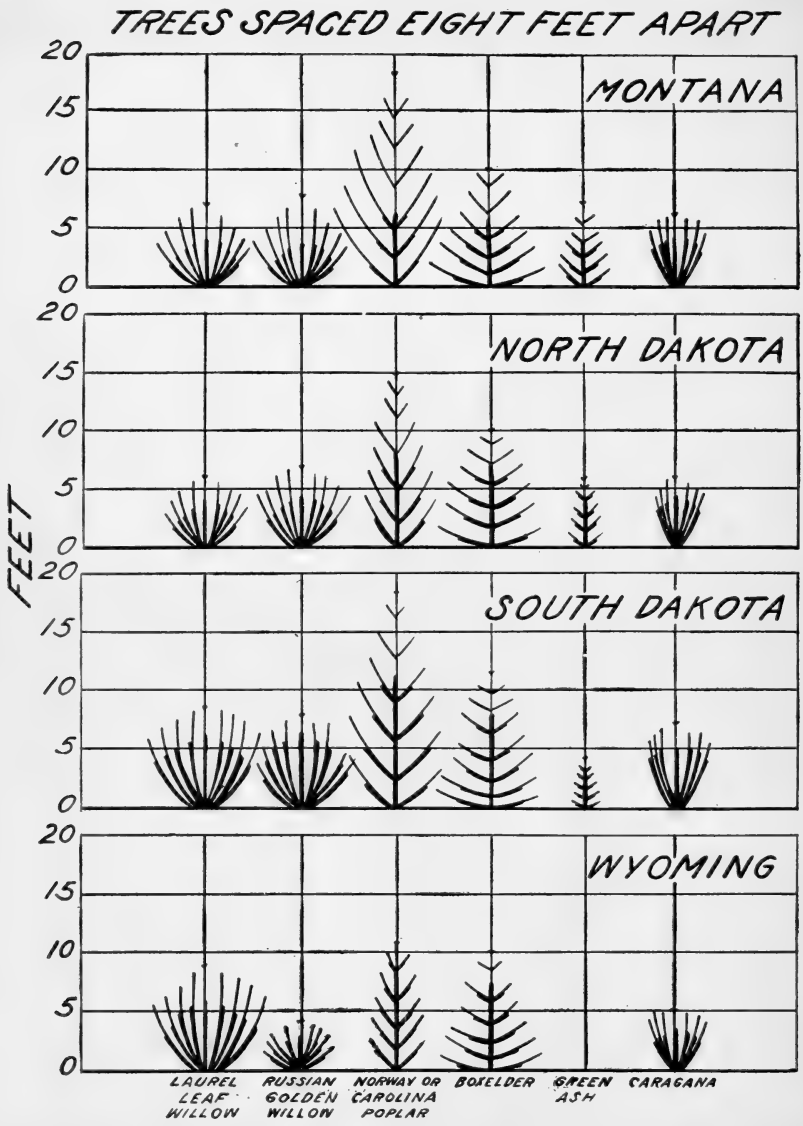

FIG. 13.—Diagrammatic representation of the average and maximum heights in 1920 of each species of tree planted as shelter belts in the States of Montana, North Dakota, South Dakota, and Wyoming in 1916. The heavy lines indicate the average growth and the light lines the maximum growth.

growing shelter belts but the interest the settlers and the farmers of the region have in them.

The actual area covered by the 716 plantings listed as successful at the close of the season of 1920 was 625 acres, or an average of 0.87 acre per planting. This acreage was divided among the four States as follows: Montana, 380 acres: North Dakota, 145 acres; South Dakota, 80 acres; and Wyoming, 20 acres.

Figure 12 is an outline map of the area in which each township (6 by 6 miles) in which one or more plantings had been made in 1917 or in which application had been made for planting in 1918 is represented by a dot. This shows the general distribution of the plantings.

TABLE 8.—*Percentage of trees of each species or kind of stock living at the end of the first season of growth each year from 1916 to 1920, inclusive.*

Year.	Plantings reported.	Species or kind of stock.									Total.
		Willow (cuttings).	Willow (rooted).	Poplar (cuttings).	Poplar (rooted).	Box elder.	Green ash.	Caragana.	White elm.	Chinese elm.	
1916	44.2	68.8	92.6	72.9	96.7	89.1	93.7	90.5	.....	.....	80.0
1917	63.4	.....	97.9	.....	.....	81.7	85.0	.....	81.2	.....	81.2
1918	34.4	.....	56.6	.....	.....	83.3	77.2	90.0	.....	88.8	72.2
1919	59.4	.....	45.6	.....	.....	72.3	68.5	78.6	.....	.....	59.4
1920	40.5	.....	.....	.....	.....	88.2	79.9	.....	.....	.....	84.8

Table 8 has been compiled from reports sent in by individual farmers at the end of each growing season. Reports are received on only about half the plantings. They contain an actual count of the dead trees and serve as a basis for furnishing replacements. Replacement planting is not practicable after the second season, as the new trees are not able to compete successfully with the older ones.

TABLE 9.—*Shelter belts planted in 1916 in which different tree species were still alive in 1920.*

State.	Plantings inspected.	Trees living (per cent).				
		Willow.	Poplar.	Box Elder.	Green ash.[1]	Caragana.
Montana	214	53.0	55.7	100	100	100
North Dakota	74	59.5	66.2	100	100	100
South Dakota	51	71.2	78.9	100	100	100
Wyoming[2]	10	60.0	50.0	100	.....	100

[1] Green ash was planted in all the shelter belts in North Dakota, but in only six in Montana, three in South Dakota, and none in Wyoming.

[2] Shelter belts in Wyoming were all in the southeastern part of the State, in Niobrara and Goshen Counties.

Table 8 shows for each year the percentage of each kind of stock living at the end of its first season in the ground and indicates the relative ease of establishing different species and kinds of stock. In the total of all species it indicates the degree of success that cooperating farmers have attained in starting their shelter belts. The high-

est percentage of stand was 84.8 in 1920 and the lowest 59.4 in 1919. The high percentage of stand in 1920 was at least partly due to the fact that only species that had proved hardy and easily established were used, while both willow and poplar are found in preceding years. The rainfall in 1916 was above normal, and in the four succeeding years it was below normal. The effect of the continued drought on the establishment of willow is clearly shown by the poor stands in 1918 and 1919 as compared with those in 1916 and 1917.

Elm does not appear after 1917. There has been no seed crop in the vicinity of Mandan from which to raise stock since that time.

GROWTH STUDY OF COOPERATIVE SHELTER BELTS PLANTED IN 1916.

During the summer of 1920 a special study was made of the shelter belts that were planted in 1916. Of 633 originally planted, as given in Table 8, 373 remained active at the beginning of the 1920 season. Of this number 349, or 94 per cent, form the basis for the data given in Tables 9 and 10.

Table 9 shows for each State the percentage of the shelter belts planted in 1916 in which the different species were living in 1920. In the 349 shelter belts studied, box elder, green ash, and caragana were living in every active planting, but willow and poplar survived in only one-half to three-fourths of the plantings active at that time. Both box elder and willow showed a better survival in South Dakota than in North Dakota, Montana, or Wyoming. This is probably due to the somewhat more favorable conditions of moisture and temperature that exist in South Dakota.

TABLE 10.—*Average and maximum height*[1] *in the summer of 1920 of the different species of trees in shelter belts planted in 1916.*

State.	Laurel-leaf willow.	Russian golden willow.	Norway or Carolina poplar.[2]	Box elder.	Green ash.	Caragana.
Montana:						
Average height.....feet....	3.75	4.25	6.50	5.75	4.00	4.00
Maximum height.....do....	7.00	7.50	18.00	10.00	7.00	6.00
North Dakota:						
Average height.....do....	4.00	4.75	7.50	6.50	4.00	4.00
Maximum height.....do....	6.00	7.00	15.00	10.00	5.50	5.50
South Dakota:						
Average height.....do....	5.50	6.00	12.00	7.50	3.50	5.00
Maximum height.....do....	9.00	7.00	18.00	14.00	4.00	7.00
Wyoming:						
Average height.....do....	5.75	3.25	8.50	7.00	.....	3.00
Maximum height.....do....	9.00	4.00	10.00	10.00	.....	5.00

[1] Two measurements were taken in each shelter belt for each species, one at a point judged to be the average height of the row and one where the trees were tallest. The maximum height given is the highest measurement found in any planting in the State.

[2] The Norway poplar and Carolina poplar were so similar in appearance that no attempt was made to distinguish between them.

In each of the 349 shelter belts studied, measurements were made of the average and maximum height of each species. A summary of

the results of this study is given in Table 10, which shows for each species the average height attained in all plantings in each State and the maximum height attained in any planting in the State.

The low average heights of willow and poplar as compared to the maximum heights are due to the continual freezing back of these species in most of the plantings. It will be noted that with the exception of green ash, all of the species made the best growth in South Dakota. As the figures for green ash in that State are based on three plantings only, they can not be considered adequate. Subsequent plantings have shown the same relatively higher growth for green ash. The comparatively better conditions as to rainfall and temperature which prevail in South Dakota will probably explain this increased growth. The data given in Table 10 are shown diagramatically in Figure 13.

FIG. 14.—An unpruned shelter belt in the third summer of growth. Planting in Valley County, Mont.

EXPERIMENTAL PLANTINGS.

In addition to the shelter-belt demonstrations under actual farm conditions, a number of special experimental plantings have been made at the Northern Great Plains Field Station.

Species testing blocks.—Since 1914 more than 80 different species of trees have been planted as pure stands in blocks containing approximately 100 trees each. These plantings are intended to serve primarily as hardiness tests. Some of the most important results from this work have been embodied in the discussion under the heading "Notes on tree species," page 6.

Methods of care for shelter belts.—Ten blocks of identical shelter-belt plantings similar to the regular demonstrations were set out in

1918. In five of the blocks the trees are spaced 4 by 4 feet and in the others 4 by 8 feet. One block of each rate of planting is not pruned, one block is moderately pruned, one block is severely pruned, one block is mulched, and one is neglected (given no cultivation). The first three blocks are given clean cultivation; the last two are not pruned.

An unpruned shelter belt in its third summer of growth in Valley County, Mont., is shown in Figure 14. A severely pruned shelter belt of the same age in Grant County, N. Dak., is shown in Figure 15. Both the effectiveness of the shelter belt and its ability to protect itself is destroyed by pruning.

Two other blocks were planted in which 4 by 12 and 8 by 8 feet spacing distances, respectively, were used. These blocks were not pruned and were given clean cultivation and with the other unpruned

FIG. 15.—A severely pruned shelter belt in the third summer of growth. Planting in Grant County, N. Dak.

blocks form a series of spacing tests. It is yet too early to present results from this series of experiments.

Species combinations.—A number of plantings were made in 1915 in which different tree species were arranged in varying combinations. This experiment was designed to determine the ability of the different species to compete with each other in adjacent rows.

SUMMARY AND CONCLUSIONS.

During the 5-year period from 1916 to 1920, inclusive, 1,234 cooperative demonstration shelter belts were planted in the Great Plains area of Montana, North Dakota, South Dakota, and Wyoming. Of this number, 716 were still growing at the close of the summer of 1920. A total of 1,488,658 trees were used in making these plantings.

Of the tree species extensively tested, the following seem adapted to the climatic conditions generally prevailing: Box elder, green ash, white elm, and caragana.

The following species which have so far been tested only in a limited way give promise of being suitable for general planting: Northwest poplar, chokecherry, buffalo berry, Russian olive, Black Hills spruce, white spruce, blue spruce, Scotch pine, and jack pine.

Extensive tests of the following species show that they are not adapted for general planting: Norway poplar, Carolina poplar, Russian golden willow, and laurel-leaf willow.

Careful preparation of the soil before planting, to conserve moisture and work out grass and weeds, is a prime requisite for successful tree planting. Clean summer fallow is the best tillage method to practice for this purpose.

Clean cultivation after planting is essential to the continued growth of young trees. Neglect in this respect for a single season is likely to result in serious damage to the trees.

Insect and animal pests may cause considerable damage unless precautions are taken against them.

With such trees as box elder, green ash, and white elm, stock raised from seed procured from native trees has shown greater hardiness than that coming from more southern and eastern localities. Seed for propagating any species for planting in shelter belts on the northern Great Plains should come from a northern source.

A standard spacing distance for trees in shelter belts has not yet been determined. Present data indicate that for the average planting site in the area the 4 by 8 feet distance used in these demonstrations is too close. Further information is needed on this point.

The experience of these five years of tree planting has shown conclusively that it is possible to start successfully a planting of trees on the average upland farm site in the northern Great Plains. Future investigation must show whether or not it is possible for such plantings to maintain themselves after they have attained their maximum growth.

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